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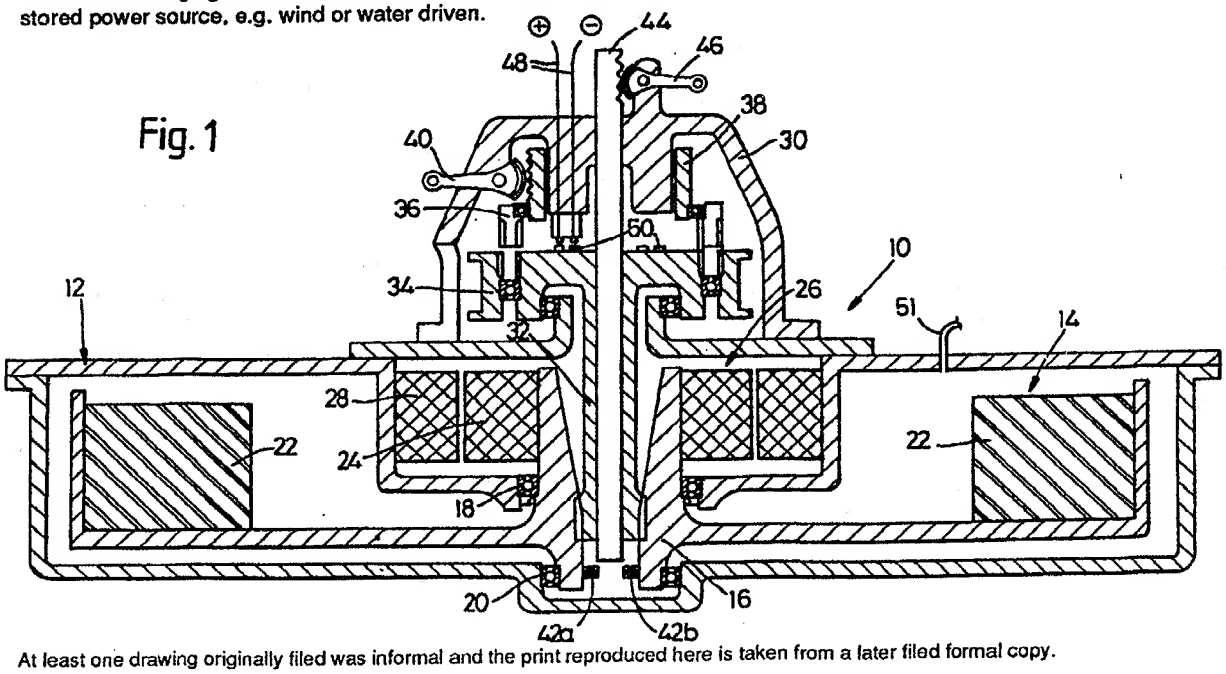
(54) Flywheel and power unit

(57) A power unit, e.g. for an electrically driven vehicle, incorporates a flywheel (14) for storing kinetic energy and a battery (22) for storing electrical energy, the battery being incorporated as a substantial part of the rotating mass of the flywheel. Preferably the unit further includes an electrical machine (26) being a motor or generator or machine operable either as a motor or a generator for transferring energy between the battery and the flywheel and/or for the input or output of rotary energy therefrom or thereto, thus the motor may be used for powering the flywheel and may also operate in a regenerative mode for recharging the unit on de-acceleration of the vehicle. The unit of the invention may also be utilized as an electrical stored power source, e.g. wind or water driven.

Fig. 1



At least one drawing originally filed was informal and the print reproduced here is taken from a later filed formal copy.

The claims were filed later than the filing date within the period prescribed by Rule 25 (1) of the Patents Rules 1990.

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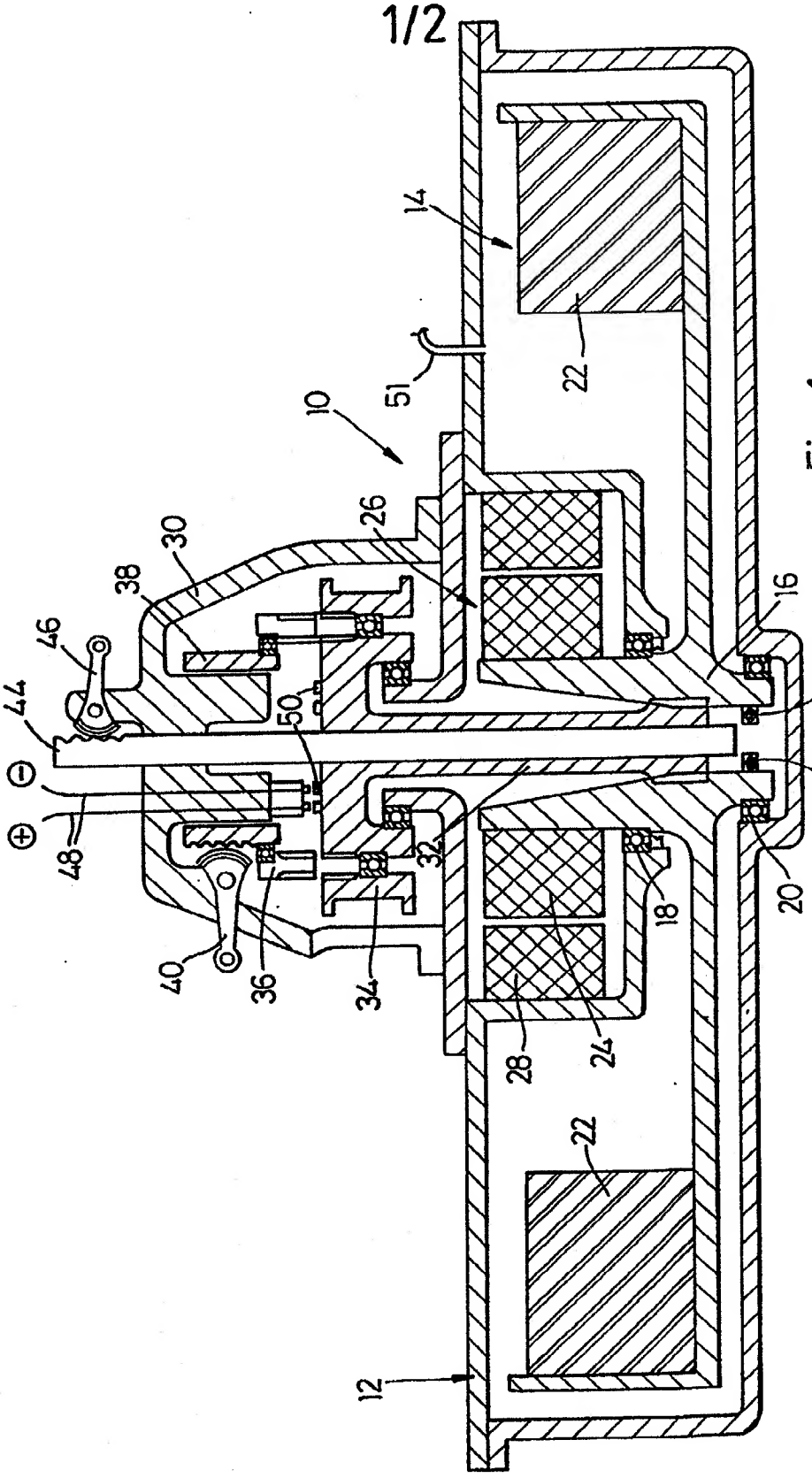
14
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Fig. 1

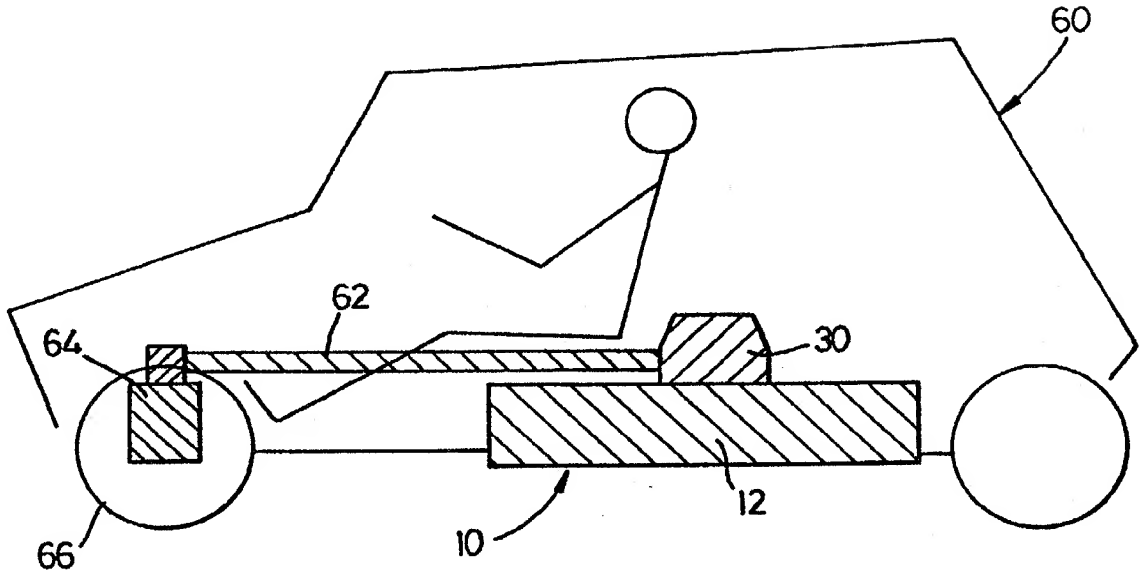

Fig. 2

POWER UNIT.

This invention relates to power units, that term being used to comprise not only units providing an output of driving power but also having the ability to convert and/or store power input.

The need to conserve natural resources and reduce or, if possible, avoid contamination of the environment, as well as economic factors, has led to increasing emphasis on the efficient use of energy, its collection and storage from renewable sources, and pollution-free operation of road vehicles and other powered equipment.

In the field of vehicle technology many attempts have been made to develop an effective free-ranging electric vehicle with only very limited success. Use of rechargeable storage batteries is theoretically attractive but, in practice, the dead weight of such batteries restricts the available power output and range of the vehicle.

Harnessing renewable power sources, such as the wind, for power generation is again attractive in theory but gives rise to problems, particularly for small scale installations, due to the wide and unpredictable variations in wind speed.

The object of the invention is to provide a power unit incorporating facility for energy conversion and storage in a particularly efficient and pollution-free manner, which is readily adaptable for use in a wide range of applications including vehicles and wind or other renewable energy powered generation facilities, and which can readily be provided as a compact unit having high power/weight ratio.

According to one aspect of the invention there is provided a power unit including a flywheel for storage of kinetic energy and a battery for storage of electrical energy characterised in that the rotatable mass of the

flywheel consists of or comprises said battery.

The unit preferably further includes a rotary electrical machine (motor and/or generator) for conversion and transfer of energy between the flywheel and the battery.

Preferably the electric machine comprises a rotor coupled to the flywheel and a co-acting stator, and said machine may be operable either as an electric motor powered from the battery for selective transfer of all or part of the resulting energy to drive the flywheel, or as an electrical generator which can be selectively energised from the flywheel and/or from rotary input to the unit to charge the battery.

Said rotor will preferably be mounted on the flywheel for rotation therewith, so forming a further part of said rotatable mass.

The flywheel may be enclosed in an airtight casing which is operatively exhausted to a low pressure to reduce energy losses caused by air friction on its rotatable mass.

The invention further resides in an electrically powered vehicle including a power unit having a flywheel selectively coupled through transmission means to one or more road wheels of the vehicle, an electrical storage battery incorporated in the flywheel to form a substantial part of the rotatable mass thereof, and an electric motor powered from the battery to drive the flywheel. The rotor of the electric motor conveniently also forms part of said mass.

Preferably the transmission means includes a continuously variable ratio drive whereby, in operation, the speed of the motor/flywheel remains substantially constant throughout the range of road speed.

It is desireable that the transmission means operates in a regenerative mode transferring kinetic energy from the motion of the vehicle to the flywheel on

de-acceleration and said regenerative effect may be carried further by said motor also being operable as an electrical generator whereby surplus kinetic energy of the flywheel may be transferred and converted to recharge the battery.

In a yet further aspect of the invention a power unit is provided for generating electric power from a rotary input, typically actuated by a renewable and substantially variable energy source such as the wind, the unit including a flywheel driven from said input for accumulating kinetic energy, a rotary electric generator driven by the flywheel, and an electrical storage battery charged from the generator, the battery forming at least a substantial part of the rotatable mass of the flywheel.

An example of the invention is now more particularly described with reference to the accompanying drawings wherein:

Figure 1 is a diagrammatic sectional view of a power unit according to the invention, and

Figure 2 is a diagrammatic representation of a road vehicle incorporating said unit.

The power unit 1 comprises a drum-like airtight casing 12 containing a flywheel assembly 14. Said assembly includes a hollow vertical main shaft 16 journalled co-axially in casing 12 on upper and lower main bearings 18, 20.

Upper bearing 18 is located in the floor of a central well defined in the top of casing 12, the upper part of shaft 16 projecting into this well. A seal is provided between the shaft and casing to prevent passage of air through the upper bearing 18.

Almost the whole of the rotating mass of the flywheel assembly 14 consists of a rechargeable electric storage battery 22, the cells of which are mounted in a balanced ring formation around the radially outer region of the assembly so that their weight is most effective in

providing or contributing to the kinetic flywheel effect. If larger or additional cells were required the battery could be extended radially inwardly towards main shaft 16. Not only does this provide a particularly compact unit but the batteries are utilized for two forms of energy storage simultaneously, both electrical energy and the kinetic energy of their revolving mass.

The upward projection of main shaft 16 mounts the rotor 24 of an electric motor 26 accommodated in the well of casing 12, the co-acting stator 28 being disposed co-axially around rotor 24. Thus rotor 24 also contributes to the total rotating mass of the flywheel assembly 14 and its windings can be connected to the rotating battery 22 without need for brushes, slip rings or the like.

The top of casing 12 mounts a co-axial bell housing 30. A hollow transmission shaft 32 has its lower end drivingly coupled to main shaft 16 and its upper end journalled within housing 30. Said upper end mounts a drive output element, in this example a pulley 34 whose flanged rim can be selectively drive-connected to or disconnected from shaft 32 by a dog clutch 36 which is shifted axially into an out of engagement by a sliding sleeve 38 on a downwardly projecting spigot formation of housing 30, the sleeve in turn being shifted by a quadrant lever 40.

The flywheel assembly 14 carries switch contacts 42a, 42b enabling the electrical circuit between the battery 22 and motor rotor 24 to be selectively opened or closed by means of an axially movable switch plunger rod 44 in sliding engagement in the hollow shaft 32, said rod being shifted by a further quadrant lever 46 pivoted on the top of housing 30.

So that battery 22 can be charged from a power source externally of unit 10 and/or so that the operation and condition of the batteries and/or motor can be monitored in operation, e.g. to check the state of charge of the batteries, electrical connections 48 are provided leading to internal slip ring contacts 50 between the

housing and the clutch hub which rotates in common with the flywheel assembly, further electrical connections (not shown) leading to battery 22 and the other electrical circuitry within the flywheel assembly (not shown).

A vacuum duct 51 will connect with an auxiliary vacuum pump (not shown) for maintaining the exhaustion of air from the casing interior. The unit is preferably mounted in a vehicle 60 (Figure 2) so that the rotational axis of the flywheel assembly is vertical to minimize gyroscopic effects, and preferably low down and substantially centrally between the road wheels for maximum stability. Pulley 34 is connected by a drive belt to transmission 62 of the vehicle (shown only schematically in Figure 2) which will preferably include a stepless infinitely variable ratio convertor (gears or pulleys) which will incorporate a conventional heavy duty clutch or other drive disengagement facility, the output being connected in conventional fashion by a final drive unit or units 64 to the driven road wheels 66 of the vehicle. A front wheel drive vehicle is illustrated but it will be appreciated that rear wheel or, indeed, four wheel drive could be employed. The body of vehicle 60 will preferably be aerodynamically designed for minimum drag and the transmission will be designed for minimum power loss.

In operation battery 22 will be charged and motor 26 connected to run the flywheel assembly up to operating speed. In the arrangement described motor 26 is used only to restore or maintain the flywheel revolutions, it does not drive the vehicle directly, the drive is taken from the kinetic energy of the rotating flywheel assembly. The motor is coupled directly to battery 22, its power output is virtually constant, and no current control between the motor and battery will normally be necessary. The power demand on the motor is independent of road and driving conditions, it will run continuously to impart kinetic energy to the flywheel up to the limiting rotational speed of the latter.

The high mass flywheel assembly 14 provides a reservoir of kinetic energy which can accommodate the power demands of the vehicle e.g. for acceleration, harnessed through the variable ratio transmission, without the need for a large or heavy duty electric motor and without danger of imposing any excess drain on the battery.

A speed sensor (not shown) is provided to detect any overspeeding of flywheel assembly 14 for automatic operation of plunger rod 44 to open switch contacts 42 and disconnect the motor from the battery until flywheel speed drops to the normal level. A further safety limit can be provided by venting casing 12 to atmosphere in the event of excessive flywheel overspeeding, so braking its rotation e.g. if the motor control should malfunction.

The vehicle will be usable when flywheel assembly 14 is operating at approximately 25% of its maximum energy level and the time taken for this flywheel speed to be achieved from initial switch on is anticipated to be around 4 minutes. With the flywheel running at optimum speed it is contemplated that a maximum of around 30 h.p. will be available for driving the road wheels, and in stop-start conditions the performance will be similar to that of an equivalent petrol driven car for around one hour duration.

The unit will operate regeneratively in that, on de-acceleration of the vehicle, the transmission ratio will be adjusted so that the road wheels transmit kinetic energy to the flywheel assembly. Not only does this provide maximum efficiency but it also saves wear and tear on the vehicle brakes. Motor 26 will normally remain switched on throughout vehicle operation, apart from the on-off switch 42 no modulation or variable control of motor current is required. The total energy reserve of the system is electrical and kinetic which increases the energy capacity by around 25% in comparison with known vehicles operating on stored electrical energy only and the power-weight ratio is enormously improved as the battery is no longer a dead weight.

It will be appreciated that the power unit of the invention could be used for applications other than general purpose vehicles such as passenger cars, it could be employed as a stationary power unit particularly where there are fluctuating or intermittent power demands but an external source of energy such as mains electricity is not readily available. The unit will operate with little noise and complete absence of pollution.

It will also be appreciated that many variations in construction and operation are possible, for example the output from the unit may be by way of gearing or shafting rather than the pulley and belt referred to above; for some applications or forms of transmission the inclusion of the clutch 36 may be unnecessary; and the shape and disposition of the components making up the flywheel assembly 14 may be substantially varied.

In some applications provision may be made for electrical regeneration as well as or possibly instead of direct kinetic regeneration, thus the electric motor employed may also be operable as a generator and, in some modes of operation, may provide current for directly recharging the batteries.

In some applications the motor or other rotary electric machine operated by the battery of the flywheel assembly will not be incorporated in or directly coupled thereto, and it need not necessarily be partly built into said assembly as described above, it could be a separate sub-assembly. It is also contemplated that a conventional power source, possibly automatically operated intermittently according to demand, could be provided for augmentation of the stored energy of the unit when required, by providing input drive for directly bringing the flywheel assembly up to speed to restore the kinetic energy reserve, and/or by operating the electrical machine to generate electric energy for augmenting the reserve stored in the battery, and/or for generating electric current externally for recharging the battery

independently of the motor or other electric machine forming part of the unit.

In another embodiment of the invention the unit is used as part of an installation for generating electrical energy by conversion of energy from a renewable source. One example of such installation is a wind-powered generator. A windmill is connected to the flywheel assembly of a unit according to the invention, said assembly incorporating or being connected to an electrical machine in the form of a generator for charging the batteries built into said assembly with electrical power output from the batteries available as and when required. Preferably the windmill itself will have automatically variable pitch blades, or it is contemplated that a variable ratio drive transmission could be used between a fixed pitch windmill and the flywheel. The flywheel assembly will have a damping or feed-back effect keeping the blades turning at a substantially constant speed regardless of wind pressure, so that the operation will be substantially unaffected by sudden gusts and lulls. The electrical generator can be matched to the mean output of kinetic energy from the flywheel so that a smaller and more efficient generator can be used; and, again, there is the very substantial power-weight ratio advantage in using the storage batteries as part of the mass of the flywheel assembly. Thus a particularly efficient and compact portable or mobile wind generator could be provided e.g. for military operations or other activities in remote places, or possibly for ships or aircraft. The same principles could be applied to a water powered or other turbo-generator.

In an application such as a vehicle the power unit of the invention might also be provided with a generation facility actuated by an external power source for recharging the batteries e.g. while the vehicle is idle. Thus the vehicle itself might carry a windmill which can be brought into operation as appropriate while the vehicle is parked; it is contemplated that a 2 metre diameter wind turbine would recharge a light duty

vehicle's batteries in around 10 hours, e.g. overnight.

The dog clutch 36 referred to above will incorporate a synchromesh device or other means for smooth engagement and disengagement while the transmission elements are running, it ensures that assembly 14 can be positively disconnected from the output pulley 34 when the vehicle is left unattended with the flywheel running for safety, and it also reduces unnecessary drag on the flywheel so as to conserve its energy while the vehicle is at rest, e.g. in traffic hold-ups or during stops, as the flywheel runs continuously during normal use.

CLAIMS

1. A power unit including a flywheel for storage of kinetic energy and a battery for storage of electrical energy characterised in that the rotatable mass of the flywheel includes the battery.

2. A unit as in Claim 1 further including a rotary electrical machine operable to convert energy for transfer between the flywheel and the battery

3. A unit as in Claim 2 wherein the electric machine comprises a rotor coupled to the flywheel and a co-acting stator.

4. A unit as in Claim 3 wherein the rotor is mounted on the flywheel for rotation therewith, so forming a further part of said rotatable mass.

5. A unit as in Claim 2, 3 or 4 wherein the electrical machine is selectively operable either as an electric motor powered from the battery for selective transfer of stored electrical energy to the flywheel, or as an electrical generator powered from the flywheel for selective transfer of stored kinetic energy from the flywheel to the battery.

6. A unit as in any preceding claim including an airtight casing enclosing the flywheel and operatively exausted to a low pressure to reduce energy losses due to air friction

7. A unit as in any preceding claim including transmission means operatively coupled to the flywheel for taking rotary power output therefrom and also operable in a regenerative mode to transfer energy from an external source for storage by the flywheel.

8. A unit as in any preceding claim including provision for electrically recharging the battery independently of the operation of the flywheel

9. A power unit substantially as hereinbefore described with reference to and as shown in the accompanying drawings

10. A powered vehicle including a power unit having a flywheel selectively coupled through transmission means to one or more road wheels of the vehicle, an electrical storage battery incorporated in the flywheel to form a substantial part of the rotatable mass thereof, and an electric motor powered from the battery to drive the flywheel.

11. A vehicle as in Claim 11 wherein a rotor of the electric motor also forms part of said rotatable mass of the flywheel.

12. A vehicle as in Claim 11 or 12 wherein the transmission means includes a continuously variable ratio drive whereby, in operation of the vehicle, the speed of the motor and flywheel remains substantially constant through a range of road speeds.

13. A vehicle as in Claim 11, 12 and 13 wherein the transmission means is operable in a regenerative mode to transfer kinetic energy from the motion of the vehicle to the flywheel.

14. A vehicle as in any one of Claims 11 to 14 wherein the electric motor is also operable as an electrical generator whereby the kinetic energy of the flywheel may be transferred and converted for recharging the battery

15. A vehicle substantially as hereinbefore described with reference to and as shown in the accompanying drawings.

16. A power unit for generating electric power from a rotary input, said unit including a flywheel driven from the input for accumulating kinetic energy, a rotary electric generator driven by the flywheel, and an electrical storage battery charged from the generator, the battery forming at least a substantial part of the

rotatable mass of the flywheel

17. A power unit as in Claim 17 wherein a rotor of the generator is mounted on the flywheel to form a further part of said rotatable mass.

18. A power unit as in Claims 17 and 18 wherein said rotary input is wind or water driven.